Detection of Water Hazards for Autonomous Robotic Vehicles

Four methods of optoelectronic detection complement each other.

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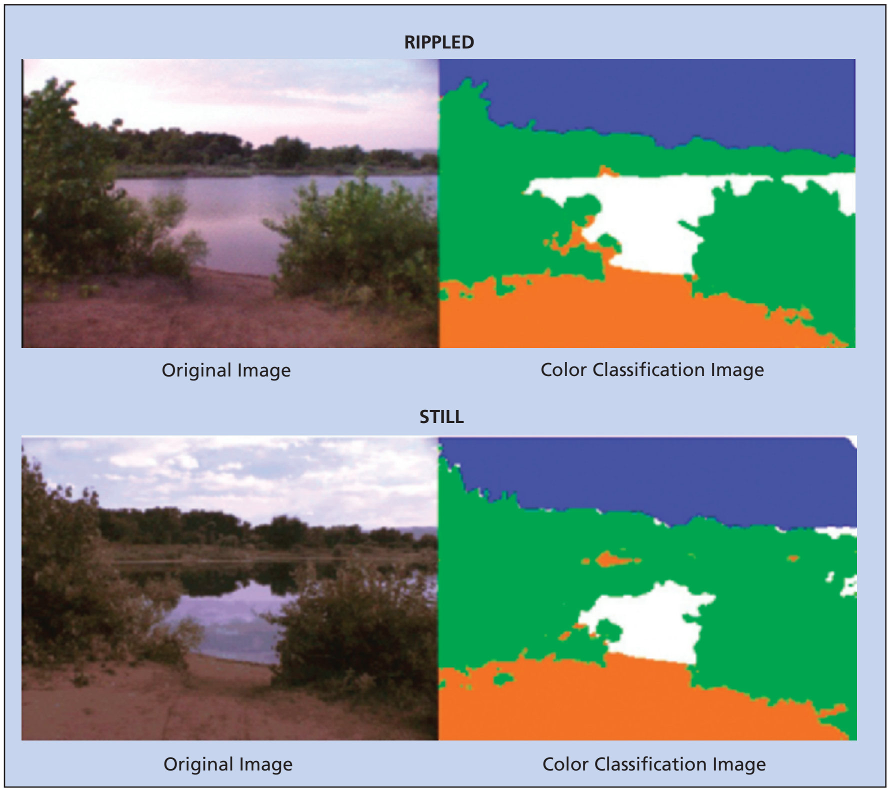
Four methods of detection of bodies of water are under development as means to enable autonomous robotic ground vehicles to avoid water hazards when traversing off-road terrain. The methods involve processing of digitized outputs of optoelectronic sensors aboard the vehicles. It is planned to implement these methods in hardware and software that would operate in conjunction with the hardware and software for navigation and for avoidance of solid terrain obstacles and hazards.

The first method, intended for use during the day, is based on the observation that, under most off-road conditions, reflections of sky from water are easily discriminated from the adjacent terrain by their color and brightness, regardless of the weather and of the state of surface waves on the water. Accordingly, this method involves collection of color imagery by a video camera and processing of the image data by an algorithm that classifies each pixel as soil, water, or vegetation according to its color and brightness values (see figure). Among the issues that arise is the fact that in the presence of reflections of objects on the opposite shore, it is difficult to distinguish water by color and brightness alone. Another issue is that once a body of water has been identified by means of color and brightness, its boundary must be mapped for use in navigation. Techniques for addressing these issues are under investigation.

The second method, which is not limited by time of day, is based on the observation that ladar returns from bodies of water are usually too weak to be detected. In this method, ladar scans of the terrain are analyzed for returns and the absence thereof. In appropriate regions, the presence of water can be inferred from the absence of returns. Under some conditions in which reflections from the bottom are detectable, ladar returns could, in principle, be used to determine depth.

The third method involves the recognition of bodies of water as dark areas in short-wavelength infrared (SWIR) images. This method is based on the fact, well known among experts in remote sensing, that water bodies of any appreciable depth appear very dark in near-infrared, overhead imagery. Even under a thick layer of marine fog, SWIR illumination is present. Hence, this method may work even in the presence of clouds, though it is unlikely to work at night. Snow and ice also exhibit very strong absorption at wavelengths greater than about 1.4 μm. Hence, the wavelength range of about 1.5 to 1.6 μm might be useable in this method for recognizing water, snow, and ice. One notable drawback of this method is that useful look-ahead distance could be limited by surface reflections.

The fourth method, intended for use at night, involves the contrast between water and terrain in thermal-infrared (medium-wavelength infrared) imagery. This method is based on the fact that at night, water is usually warmer than the adjacent terrain. Look-ahead distance could be limited in this method because, for reasons not yet fully understood, water appears to darken in the thermal infrared with increasing distance.



Images of the Chatfield Reservoir in Denver were acquired under rippled and still surface conditions, then pixels were classified by color. In the synthetic color classification images, white represents water, brown represents soil, green signifies vegetation, and blue signifies anything else. In the rippled case, all of the water is correctly labeled. In the still case, water reflecting the sky is correctly classified, but water reflecting trees is erroneously classified as vegetation.

This work was done by Larry Matthies, Paolo Belluta, and Michael McHenry of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*

The software used in this innovation is available for commercial licensing. Please contact Karina Edmonds of the California Institute of Technology at (818) 393-2827. Refer to NPO-40369.